NC STATE
Wilson College of Textiles

JTATM
Journal of Textile and Apparel, Technology and Management

Volume 11, Issue 4, 2020

Thermal, Permeability and some Dimensional Characteristics of Knitted Fabrics Made from 100% Cotton and Cotton/Elastane Yarns

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ABSTRACT

The thermal properties (thermal conductivity, thermal resistance and actual insulating), permeability properties (water and air) and some dimensional properties (thickness, shrinkage, width) and wicking ability of single jersey, 1x1rib, interlock, single pique and two thread fleece knitted fabrics made from 100%cotton and cotton/Elastane yarns (5%Elastane yarn content) are investigated, in this research. The 5% Elastane yarn is used in this study because many knitting factories and users add an Elastane at this ratio to improve the extensibility of fabrics. The sample fabrics well-conditioned for 24 hours at 20^{o}C temperature and 66% relative humidity (RH). As revealed in the result, the thermo-physiological comfort properties of knitted fabrics are influenced by the type of fibers from which the yarns are made. It is found that the thermal (resistance, conductivity and insulation), thickness, shrinkage, width, air and water permeability and wicking ability of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics made from 100%cotton and cotton/Elastane yarns are significantly different from each other. The overall emphasis of this study was to study the effect of the different materials on thermo-physiological properties of widely produced knitted fabrics.

Keywords: Cotton, Cotton/Elastane, knitted fabrics, thermo-physiological properties

1.0 Introduction

Weft knitted fabrics have greater extensibility, form fitting and comfortable properties. Because of these properties knitted fabrics demand has become increasing in all over the world. The material type, property and process parameters influence the characteristics of knitted fabrics. Weft knitted fabrics made from different materials have different characteristics[1, 2]. Weft knitted fabrics are widely used due to their formability and improved drape ability[3, 4].

The human body strives to keep its core temperature at 37^{o}C and the metabolic heat generation for a person engaged in physical activity is in the range of 800-1300W. The extra body heat is produced causing the nervous system to react by sweating. Sweat glands pump perspiration through pores, body heat is transferred to the sweat, causing it to evaporate and cool the body [5, 6]. The impact of clothing on comfort and performance of individuals at work or sport are of particular importance because physiological loads may decline the physical and mental capacity of the person [7]. Wear comfort can be divided into physiological, psychological, ergonomic and skin sensorial aspects[8]. Thermo- physiological comfort property is a general expression of factors such as the water vapor transmission, sweat absorption, thermal properties and drying ability of textile products [9-11].

Air permeability is defined as volume of air in cm^3 passes through 1 cm^2 of fabric in 1 second at a pressure difference of 10 mm head of water[12]. Air permeability is deciding factor of comfort property of a fabric, as it plays a role of transporting air and moisture vapor to the outside atmosphere from the skin and fresh air from the atmosphere to the skin of human body. The assumption is like that; the vapor travels mainly through the free spaces of fabric by diffusion in air from one side of the fabric to the other. The water vapor transmission, thermal conductivity and wicking ability of textile products are determined by the air permeability properties of knitted fabrics [12, 13].

Fiber type, yarn type and property, fabric structure, knitted fabrics dimensional properties, porosity and state of knitted fabrics are the main factors those affect the comfort (air and water permeability, thermal conductivity, resistance, insulation and wicking ability) properties of the fabric[14-21]. It was found that air permeability, contrary to water vapor permeability, is a function of the thickness and surface porosity of knitted fabrics[22, 23].

The enclosed still air and external air movement are the main factors which influence heat transfer through fabric [24, 25] and it is influenced by the material, thickness and fabric construction[26]. Water vapor permeability plays a very important role when there is only little sweating, or insensible perspiration or else very little sweating [27-30]. Thermal conductivity is an intensive property of sportswear that indicates ability to conduct heat. Thermal conductivity of knitted fabrics increased with increased stitch density, reduced thickness(greater is the air trapped in the loop structure which gives lower thermal conductivity value)[31] and reduced insulation and resistance [17, 23].

As reviewed in different research articles and books, the thermo-physiological properties of knitted fabrics made from 100%cotton and cotton/Elastane yarns have not been studied in detail except on single jersey. But, this paper studies the thermo-physiological properties such as thermal conductivity, thermal resistance, actual insulating, thickness, shrinkage, width, air and water permeability and wicking ability of knitted fabrics such as single jersey, 1x1rib, interlock, single pique and two thread fleece made from 100% cotton - and cotton/Elastane (95/5%blended) yarns. Though many researchers investigated the effect of spandex yarn as core spun in cotton fiber, in this research Elastane is used as naked filament with the cotton spun yarn (not skin friendly with cotton fiber). Comparative discussions between structures, yarn types and properties are done in this study.

2.0 Materials and Experiments

2.1 Materials

An Elastane accounts for about 5% content (40denier = 133Ne) while cotton accounts for 95% content (35Ne) in the 28Ne combed cotton/Elastane blended yarn (cotton/Elastane = 95/5%) and an Elastane is fed to the needles as naked filament with the cotton yarn in the same yarn feeder(carrier)

which is neither plied nor core spun with cotton. Cotton fiber harvested from Upper Awash-Ethiopia has 28mm staple lengths, 12.8 short fiber index, 300 neps, 4.06% trash, 4.2 micronaire fineness. The yarns used for this study were produced from 100%cotton and cotton/Elastane yarns with the properties shown in Table 1.

Table 1: Yarn specifications

Twist (1/m)	Ne	U%	CVM	Thin_50%	Thick+50%	Neps+200%	TIP	Elastane count
750	35	9.21	11.70	0	33.6	29.8	63.4	133Ne

The single jersey, single pique and two thread fleece are produced by the single bed circular knitting machine while rib and interlock by double bed circular knitting machines with the machine parameters shown in Table 2.

Table 2: Machine parameter

S/NO.	Knitting machine for	Needles	Diameter	Gauge	Cam tracks	Feeders	Machine speed
1	Single jersey	2976	34	28	4	108	30rpm
2	Interlock	2630	30	24	2	112	14
3	Rib	2630	30	18	1	94	20

The study was carried out by keeping these materials and their parameters constant except for the yarn's (type of raw material).

In the sample knitted fabrics, the loop lengths were set with equal value in the knitting machine. However, during the knitting process, the fabrics will have different loop lengths due to transferring of the loop and staying idles in the rib and interlock knitting machines and the floats at the technical back of fleece knitted fabrics. There are 28 needles per inch in a cylinder in single jersey, single pique and fleece. In 1x1rib knitting machines, there are 18 needles per inch in cylinder and 18 needles per inch in dial. In interlock knitting machines there are 24 needles per inch in cylinder and 24 needles per inch in dial. The working principle and arrangement of needles in 1x1rib and interlock knitting machines is different in gaiting [32].

2.2 Experiments

Single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics were produced for this study and prepared for laboratory investigations. Thickness, width, shrinkage, thermal conductivity, thermal resistance, actual insulating, wicking ability and water permeability of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics made from 100%cotton and cotton/Elastane yarns are used in this study and the following tests are done.

i. *Yarn properties*
U% (irregularity), CVM (coefficient of variation in mass), Thin and Thick places and the amount of Neps in cotton yarn are the yarn properties tested for this study. This was done using Uster tester-5 machine and Uster testing standards.

ii. *Thickness*
The thickness of single knitted fabrics tested using digital thickness tester as directed in ASTM D1777-02Standard Test Method for Thickness of Textile Materials[33].

iii. *Air permeability*
The air permeability of samples tested using digital thickness tester as directed in ASTM D737 – 04 Standard Test Method for Air Permeability of Textile Materials [12]. The measurement unit used in this experiment is $cm^3/cm^2/s$.

iv. *Thermal Conductivity*
Thermal conductivity of knitted fabrics have been tested using digital thermal interface material tester (TIM 1300A) as directed in ASTM D5470 standards.

v. *Thermal Resistance*
Thermal resistance of knitted fabrics tested using digital thermal interface material tester (TIM 1300A) as directed in ASTM D5470 standards[34].

vi. *Actual Insulating(R)*
Actual insulating(R) of knitted fabrics tested by digital thermal interface material tester (TIM 1300A) as directed in ASTM D5470 standards[34].

vii. *Water permeability*
Water permeability of knitted fabrics tested using hydrostatic head, which is a measure of the opposition to the passage of water through the fabric as directed in ISO 811-2018(en) standard[35].

viii. *Wicking ability*
The wicking ability of sample knitted fabrics tested using the vertical wicking as directed in AATCC 197 test method[36].

3.0 Result and Discussion

3.1 Thickness

The thickness of single jersey, 1×1rib, interlock, single pique and fleece knitted fabrics made from 100% cotton and cotton/Elastane (95/5%) blended yarns is different (see Table 3). The thickness of knitted fabrics made from 100%cotton are lower than the same fabrics made from cotton/Elastane blended yarns because the fabrics made from cotton/Elastane yarns have greater widthwise shrinkage which leads to higher thickness of the fabrics. The thickness of interlock knitted fabric made from 100%cotton and cotton/Elastane yarns is the highest as compared to the other knitted fabrics made from the same materials because interlock is made when two 1x1rib loops are locked together and appears in the technical face of loops in addition to the shrinkage of fabrics. Single jersey has the lowest thickness in both 100%cotton and cotton/Elastane yarns as compared to the other fabrics made from the same materials because of two reasons. Firstly, single jersey is made on one needle bed with one set of needles and has single faced appearance as compared to interlock and 1x1rib knitted fabrics. Later, in single jersey only one yarn is fed to needles and one loop is formed at each needle continuously while in single pique knitted fabric each stitch is formed from one tuck loop, one held loop and one knit loop while in fleece knitted fabric two yarns floating at the technical back of the fabric, which gives more thickness as compared to single jersey made from the same yarns.

In Table 3, the mean, standard deviation, standard error, minimum and maximum values of the test specimens are shown. The standard deviations of all sampled fabrics made from 100%cotton and cotton/Elastane are similar with slight deviations from their mean. This shows that the values in a statistical data set are closest to the mean of the data set, on average.

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Table 3: Description for thicknesses of knitted fabrics made from 100%cotton (C) and cotton/Elastane (C/E) yarns

Type of Fabrics	Yarns	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Single jersey	C/E	0.75	0.03	0.01	0.72	0.78
	C	0.62	0.01	0.00	0.60	0.65
1x1Rib	C/E	1.33	0.02	0.01	1.29	1.37
	C	0.84	0.02	0.01	0.81	0.85
Interlock	C/E	1.50	0.02	0.01	1.46	1.52
	C	1.25	0.01	0.00	1.23	1.28
Pique	C/E	1.03	0.03	0.01	0.99	1.08
	C	0.75	0.02	0.01	0.71	0.78
Two thread fleece	C/E	1.43	0.03	0.01	1.38	1.48
	C	0.92	0.02	0.01	0.90	0.95

The thickness of single jersey, single pique, 1x1rib, interlock and fleece knitted fabrics mean differences are significant at 0.05 confidence level. As shown in Table 4, the thickness of single jersey is significantly influenced by the presence of 5% Elastane in the Upper Awash combed cotton yarn 1x1Rib knitted fabrics have the highest F-Value as compared to other knitted fabrics which shows that 1x1rib has a high dispersion rate as compared to other knitted fabrics.

3.2 Shrinkage and Width

Shrinkage (%) of knitted fabrics is calculated from machine gauge and wales per centimeter as:

$$\%Shrinkage(S) = \frac{\text{Wales per inch} - \text{Gauge of the machine(inch)}}{\text{Wales per inch}} x100.$$

As shown in Table 5, the shrinkage (%) of knitted fabrics made from 100%cotton is lower as compared to the same fabrics made from cotton/Elastane blended yarn because knitted fabrics made from cotton/Elastane yarns have greater elastic recovery property from extension as compared to cotton yarn alone. The shrinkage percent of 1x1rib knitted fabric made from 100%cotton and cotton/Elastane yarns is highest as compared to the other knitted fabrics made from the same yarns because 1x1rib is made when the two consecutive technical face and reverse loops are meshed on one side of the fabric and appears as a vertical corrugation in both sides of the fabric. These technical face and reverse meshed loops on one side of the fabric leads to a high shrinkage percent opposite to its corrugation. As shown in Table 5, the two-thread fleece has the lowest shrinkage in both 100%cotton and cotton/Elastane yarns as compared to the other fabrics made from the same materials. Fleece knitted fabrics have two floating threads at the back of the fabric. These floats provide dimensional stability by increasing the fabric bulkiness at the back in order to minimize the widthwise shrinkage of the fabric.

The shrinkage of knitted fabrics increased due to the presence of 5% Elastane in the cotton yarns This is because an extended Elastane yarn length is recovered to its original size than ure cotton yarn when the needles pulling force is released from the loops. An ascending order of shrinkage percent of the fabrics is fleece, single pique, single jersey, interlock and 1x1rib. The 1x1Rib and interlock knitted fabrics made from 100% cotton shrink more than fleece, single pique and single jersey knitted fabrics made from cotton/Elastane. So, yarn types may not have the same effect on shrinkage rate of different types of knit structures.

Shrinkage of knitted fabrics inversely related to an actual width of knitted fabrics

(Width (cm)= $\frac{\text{Number of needles(N)}}{\text{Wales per centimeter(wpc)}}$). As shown in Figure 1, the width of two-thread fleece is highest as compared to other fabrics made from the same materials whereas 1x1rib has the lowest width as compared to other fabrics made from the same materials.

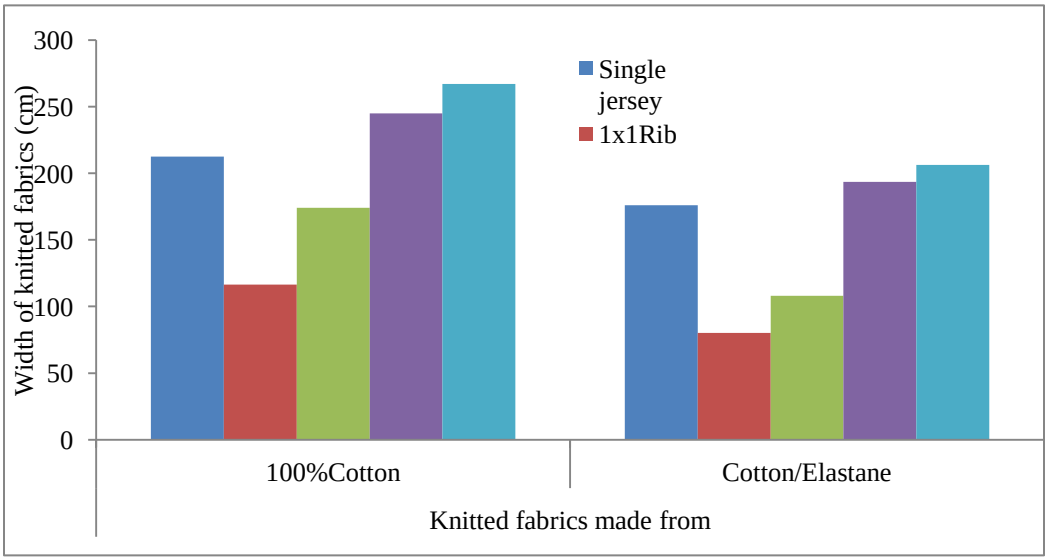

Figure 1: Width of knitted fabrics made from 100%cotton and cotton/Elastane yarns

In Table 5 the mean, standard deviation, standard error, minimum and maximum values of shrinkage of the test specimens are shown. The standard deviations of all sampled fabrics (except interlock) made from 100%cotton(C) and cotton/Elastane(C/E) are similar with slight deviations from their mean. This shows that the values in a statistical data set are closest to the mean of the data set, on average, except in interlock knitted fabric.

Table 5: Description for shrinkage of knitted fabrics made from 100%cotton and cotton/Elastane (95/5%)

Fabric types	Yarns	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Single jersey	C/E	34.55	1.58	0.50	33.19	37.01
	C	22.35	1.40	0.44	21.26	23.98
1x1Rib	C/E	79.74	0.61	0.19	79.16	80.32
	C	70.68	0.70	0.22	69.98	71.65
Interlock	C/E	54.79	2.11	0.67	52.76	58.92
	C	27.20	0.83	0.26	26.18	28.42
Single pique	C/E	28.26	1.44	0.46	26.51	30.32
	C	9.26	1.23	0.39	8.14	11.10
Two thread fleece	C/E	23.58	1.68	0.53	21.26	26.02
	C	1.00	2.15	0.68	-1.13	4.97

The shrinkage of knitted fabrics mean differences are significant at 0.05 levels. As shown in Table 6, the shrinkage of knitted fabrics is significantly influenced by the presence of 5% Elastane in the Upper Awash combed cotton yarn knitted fabrics. An interlock has the highest F-Value as compared to other knitted fabrics, which showed that interlock fabric has a high dispersion rate as compared to the other knitted fabrics.

Table 6: Analysis of variances for shrinkage of knitted fabrics made from 100%cotton and cotton/Elastane

Type of fabrics	F	Sig.
Single jersey	332.87	0.00
1x1Rib	943.75	0.00
Interlock	1486.62	0.00
Single pique	1005.60	0.00
Two thread fleece	683.91	0.00

3.3 Air and Water permeability

The air and water permeability of the selected knitted structures made from 100%cotton and cotton/Elastane (95/5%) blended yarns is different. As shown in Figure 2 and Figure 3, the air and water permeability of knitted fabrics made from 100%cotton is higher than the same fabrics made from cotton/Elastane blended yarn because the fabrics made from cotton/Elastane yarns have greater widthwise shrinkage and thickness that leads to reduced permeability of the fabrics.

The air permeability of 1x1rib knitted fabric made from 100%cotton and cotton/Elastane yarns is the highest as compared to the other knitted fabrics made from the same materials because 1x1rib has high loop length, low stitch density and low shrinkage which allows the air to pass through the cords (face loop lines) of the fabrics. Single jersey has the lowest air permeability in both 100% cotton and cotton/Elastane yarns as compared to the other fabrics made from the same materials because single jersey has more shrinkage and low loop length.

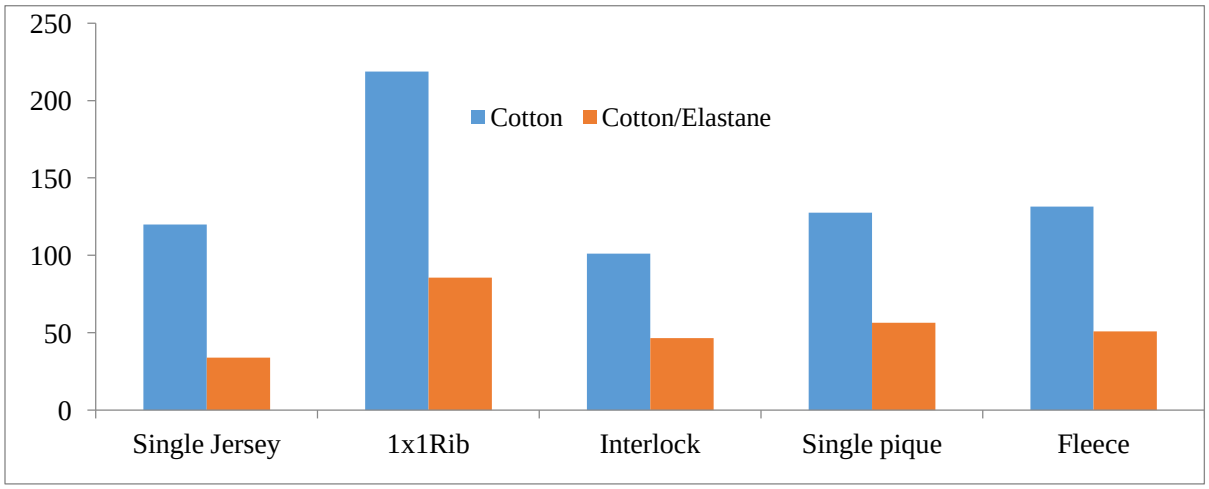

Figure 2: Air of knitted fabrics made from cotton and cotton/Elastane

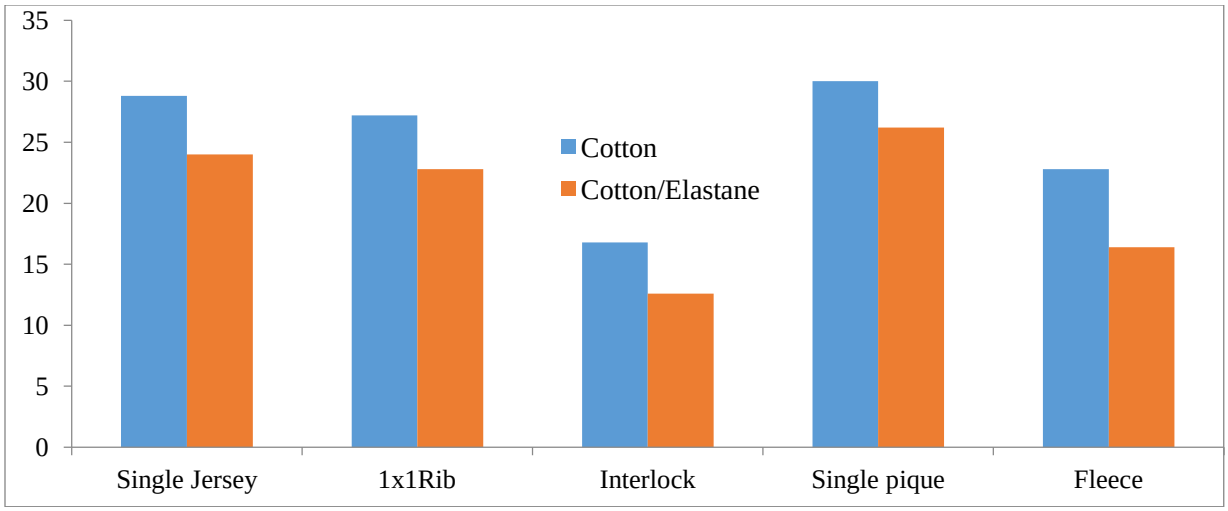

Figure 3: Water permeability of knitted fabrics made from cotton and cotton/Elastane

As shown in Table 7, the thickness, Wales per centimeter, shrinkage and loop length of knitted fabrics increased with cotton/Elastane blended yarn as compared to 100% cotton yarn. But, the tightness factor of these fabrics is lower with Cotton/Elastane (C/E) blended yarns than with 100% cotton(C).

Table 7: Relationship of air permeability with some of dimensional properties of knitted fabrics

Type of Fabric	Loop length in mm	Wales per cm	Thickness in mm	Tightness factor	Shrinkage in %	Air permeability in $cm^3/cm^2/s$
Single jersey (C)	2.94	13.95	0.62	2.12	20.90	119.86
Single jersey(C/E)	3.03	22.90	0.75	1.77	33.19	33.96
1x1Rib (C)	3.09	15.50	0.84	1.67	28.88	218.80
1x1Rib (C/E)	3.52	21.90	1.33	1.28	48.72	85.69
Interlock(C)	2.17	14.30	1.25	2.41	22.91	101.20
Interlock (C/E)	2.60	19.60	1.50	1.77	43.75	46.47
Single pique (C)	2.44	15.37	0.75	1.77	9.26	127.60
Single pique	2.99	12.15	1.03	2.17	28.26	56.45
Fleece(C)	3.61	14.43	0.92	1.26	1.00	131.50
Fleece(C/E)	4.20	11.14	1.43	1.67	23.58	50.94

The air permeability property of knitted fabrics is inversely proportional to tightness factor, Wales per centimeter, shrinkage percent and thickness, but directly proportional to loop length of knitted fabrics. As shown in Table 7, knitted fabrics made from cotton/Elastane yarns have higher shrinkage percent, thickness and Wales per centimeter and the air permeability property of knitted fabrics is reduced. Though the loop length of knitted fabrics is high with cotton/Elastane yarn, the air permeability is reduced due to the higher shrinkage percent of knitted fabrics for the

presence of 5%Elastane yarn in 95% cotton. The increasing order of air permeability property of knitted structures made from 100% cotton and cotton/Elastane blended yarns is single jersey, interlock, fleece, single pique and 1x1rib.

The water permeability of single pique knitted fabric made from 100% cotton and cotton/Elastane yarns is the highest as compared to the other knitted fabrics made from the same materials because single pique has more porosity due to the change of loop shape (inverted U-shape loop) during knitting for tuck loop formation. Interlock has the lowest water permeability in both 100% cotton and cotton/Elastane yarns as compared to the other fabrics made from the same materials in two reasons. Firstly, an interlock is made when two 1x1 rib loops are locked together with reduced porosity and increased thickness. Secondly, two yarns are given to the needles and four loops are formed at one cycle, continuously. These reduced the water permeability of interlock knitted fabric as compared to other fabrics made from the same yarns.

Table 6 shows the mean, standard deviation, standard error, minimum and maximum values of the test specimens. The standard deviations of all sampled fabrics made from 100% cotton and cotton/Elastane are similar with slight deviations from their mean.

Table 8: Description of air and water permeability of knitted fabrics made from 100%cotton (C) and cotton/Elastane(C/EL) yarns

Knitted fabrics	Yarn	Std. Deviation		Std. Error		Minimum		Maximum	
		Air	Water	Air	Water	Air	Water	Air	Water
Single jersey	C/EL	3.01	1.00	0.95	0.45	29.00	23.00	38.70	25.00
	C	10.22	0.84	3.23	0.37	96.60	28.00	132.00	30.00
1x1Rib	C/EL	5.56	1.30	1.76	0.58	75.80	21.00	95.80	24.00
	C	19.01	0.84	6.01	0.37	185.00	26.00	250.00	28.00
Interlock	C/EL	2.25	0.89	0.71	0.40	43.80	12.00	49.80	14.00
	C	4.87	1.10	1.54	0.49	95.50	15.00	109.00	18.00
Single pique	C/EL	4.13	0.84	1.31	0.37	48.00	25.00	62.00	27.00
	C	4.93	1.00	1.56	0.45	120.00	29.00	134.00	31.00
Fleece	C/EL	2.24	1.14	0.71	0.51	48.00	15.00	54.80	18.00
	C	4.74	1.79	1.50	0.80	124.00	21.00	141.00	25.00

As shown in Table 9, the air and water permeability of knitted fabrics are significantly influenced by the presence of 5% Elastane in the Upper Awash combed cotton yarn at 0.05 level. Fleece knitted fabrics air permeability and single jersey water permeability have the highest F-Value as compared to other knitted fabrics that shows that the fabrics have high dispersion rate as compared to other knitted fabrics.

Table 9: Analysis of variance for air and water permeability of knitted fabrics

Knit Structures	F		Sig.	
	Air	Water	Air	Water
Single jersey	650.62	67.77	0.00	0.00
1x1Rib	451.73	40.33	0.00	0.00
Interlock	1042.63	44.10	0.00	0.00
Single pique	1224.61	42.47	0.00	0.00
Two thread fleece	2358.22	45.51	0.00	0.00

3.4 Wicking ability

As shown in Table 10, the wicking ability of knitted fabrics made from 100% cotton and cotton/Elastane (95/5%) blended yarns is not different in the different type of yarns at different wicking times (at 10minute, 30minute, and 60minute). However, the vertical wicking ability (height in cm) is different between structures at different wicking time. The wicking ability of all knitted fabrics made from 100% cotton and cotton/Elastane yarns is 0 cm zero) at 10minute vertical wicking time. As revealed in the result, the wicking ability of knitted fabrics is not influenced by the blend of the yarns. However, the fabric structure and the wicking time are the main factors to determine the wicking ability of the knitted fabrics. The wicking ability is dependent on the thickness of the knitted fabrics. With this regard single jersey, single pique, 1x1rib, two thread fleece and interlock knitted fabrics made from 100% cotton (C) and cotton/Elastane (C/E) yarns are in the increasing order of the vertical wicking ability with an increased wicking time (see Table 10).

Table 10: Wicking ability of knitted fabrics made from 100%cotton (C) and cotton/Elastane (95/5%) (C/E) yarns

Fabric types		Wicking height at different wicking timings		
		Vertical wicking height at 10 minute(cm)	Vertical wicking height at 30 minute (cm)	Vertical wicking height. at 60 minute (cm)
Single jersey made	C	0	0	1
	C/E	0	0	1
1x1Rib	C	0	1	3
	C/E	0	1	3
Interlock	C	0	6	7
	C/E	0	6	7
Single pique	C	0	0	2
	C/E	0	0	2
Fleece	C	0	4	5
	C/E	0	4	5

3.5 Thermal Conductivity, Resistance and Actual Insulation

The thermal conductivity, resistance and actual insulation of knitted fabrics measured and the results are shown in Figure 4. The thermal conductivity of knitted fabrics made from 100%cotton is higher than the same fabrics made from cotton/Elastane blended yarn. The thermal conductivity of single jersey made from 100%cotton and cotton/Elastane yarns is highest as compared to the other knitted fabrics made from the same yarns because single jersey is lower in

thickness and shrinkage that allows heat to transmit through it. Similarly, interlock made from 100% cotton and cotton/Elastane blended yarns has the lowest thermal conductivity as compared to the other fabrics made from the same yarns because of two reasons. Firstly, an interlock knitted fabric is made when two 1x1 rib loops are locked together with reduced porosity and increased thickness. Secondly, in interlock, two threads are fed to the needles and four loops are formed at one cycle, successively. These reduce the thermal conductivity of interlock knitted fabric as compared to other fabrics made from the same yarns. The increasing order of thermal conductivity of knitted fabrics is interlock, 1x1 rib two thread fleece, single pique and single jersey (see Figure 4).

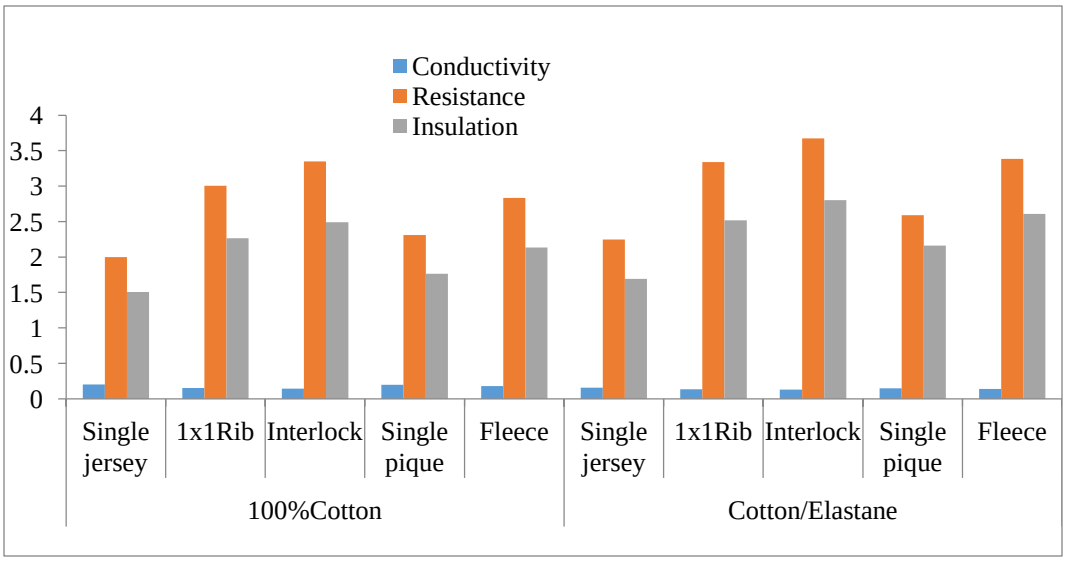

Figure 4: Thermal properties of knitted fabrics made from 100%cotton and cotton/elastane yarns

The thermal conductivity of knitted fabrics decreased due to the presence of 5% Elastane in cotton yarns. This is because an Elastane yarn (Polyurethane fiber thermal conductivity = 0.022W/mK and cotton fiber thermal conductivity = 0.04W/mK) has lower thermal conductivity and knitted fabrics made from this yarn has highest shrinkage and increased thickness. On contrary, thermal resistance and actual insulation appears as the opposite of thermal conductivity (see Figure 4). The addition of Elastane yarn in the pure cotton fiber reduces the porosity and increases the thickness and shrinkage of knitted fabrics. These provide knitted fabrics with low thermal conductivity, high thermal resistance and high insulation.

In Table 11, the mean, standard deviation, standard error, minimum and maximum values of the test specimens are shown. The knitted fabrics made from cotton/Elastane and 100% cotton yarns have different standard deviations due to the values in a statistical data set shows different closeness to the mean of the data set, on average.

Table 11: Description for thermal properties of knitted fabrics made from 100% cotton and cotton/Elastane yarns

Fabric types	Yarn types	Std. Deviation			Std. Error			Minimum			Maximum		
		Con	Res	Ins	Con	Res	Ins	Con	Res	Ins	Con	Res	Ins
Single Jersey	C/E	0.02	0.10	0.07	0.01	0.03	0.02	0.14	2.10	1.58	0.21	2.40	1.81
	C	0.01	0.15	0.11	0.00	0.05	0.04	0.19	1.78	1.34	0.23	2.21	1.66
Rib	C/E	0.00	0.31	0.23	0.00	0.10	0.07	0.13	2.96	2.23	0.14	3.83	2.89
	C	0.01	0.15	0.11	0.00	0.05	0.04	0.14	2.72	2.05	0.17	3.22	2.43
Interlock	C/E	0.00	0.11	0.12	0.00	0.03	0.04	0.13	3.51	2.68	0.13	3.85	2.99
	C	0.01	0.29	0.12	0.00	0.09	0.04	0.13	2.54	2.22	0.15	3.55	2.64
Single Pique	C/E	0.01	0.10	0.13	0.00	0.03	0.04	0.14	2.46	1.87	0.16	2.73	2.26
	C	0.01	0.14	0.07	0.00	0.04	0.02	0.19	1.99	1.68	0.21	2.51	1.89
Fleece	C/E	0.01	0.14	0.09	0.00	0.05	0.03	0.13	3.19	2.45	0.15	3.57	2.71
	C	0.01	0.29	0.22	0.00	0.09	0.07	0.17	2.40	1.81	0.19	3.26	2.46

The thermal conductivity(Con), resistance (Res) and actual insulation(Ins) of single jersey, single pique, 1x1rib, interlock and fleece knitted fabrics mean differences are significant at 0.05 levels (see Table 12).

Table 12: Analysis of variances thermal conductivity of knitted fabrics made from 100%cotton and cotton/Elastane yarn

Fabric Types	F			Sig.		
	Con	Res	Ins	Con	Res	Ins
Single Jersey	39.88	19.41	19.45	0.00	0.00	0.00
Rib	58.87	9.44	9.43	0.00	0.01	0.01
Interlock	46.06	10.97	33.28	0.00	0.00	0.00
Single Pique	403.63	27.27	76.90	0.00	0.00	0.00
Fleece	184.43	29.04	40.40	0.00	0.00	0.00

4.0 Conclusion

The thermo-physiological properties such as thermal conductivity, thermal resistance, actual insulating, air and water permeability, wicking ability, thickness, shrinkage and width of knitted fabrics such as single jersey, 1x1rib, interlock, single pique and two thread fleece made from 100% cotton and cotton/Elastane yarns have been investigated. As revealed in the results and discussion, the 5% elastane content in the combed cotton yarn changes the thermo-physiological properties of knitted fabrics, significantly. These properties are interrelated one to the other and have an effect on each other. Thickness of knitted fabrics increased while the air and water permeability of knitted fabrics reduced due to the presence of 5% Elastane yarns in the 95% cotton yarn. The type of knit structures and the time of wicking rather than the type of fibers (100% cotton and cotton/Elastane) from which the fabric is made influence the wicking ability of knitted fabrics. The width of knitted fabrics reduced with cotton/Elastane yarns as compared to the same fabrics made from 100%cotton (cotton alone). This is due to the high shrinkage tendency of knitted fabrics made from cotton/Elastane blended yarns than from 100%cotton. The physical properties such as thickness, air and water permeability influences the thermal properties of knitted fabrics. Thermal conductivity of knitted fabrics reduced while thermal resistance and insulation increased due to the presence of 5% Elastane yarns in cotton yarn because an

Elastane yarn increases the thickness and shrinkage of knitted fabrics and reduces the air and water permeability in addition to Elastane's low thermal conductivity (0.022W/mK).

Acknowledgement

This research was completed with the help of MAA Garment and Textile Factory (Located in Mikelle, Ethiopia) and Ethiopian Institute of Textile and Fashion Technology (EiTEX @ Bahir Dar University, academic institution). The staffs of these organizations have been the core investigators for this work. This research is done under an employer (Ethiopian Institute of Textile and Fashion Technology (EiTEX @ Bahir Dar University, academic institution) support.

Data Availability

The data used in this manuscript are open access data in the literature. The data used in the Tables and Figures are the author's original/virgin data found from testing.

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